AFRL Fire Research Group Capabilities and Research on Aerospace Composite Materials

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ARFF Working Group, April 2006

Distribution Status A (Approved for Public Release; Distribution unlimited) .
Date of Determination: March 30, 2006

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*

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1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
01-05-2005	Interim Technical Paper	01-10-2003 -- 30-09-2005

4. TITLE AND SUBTITLE
Responding to Composite Fires: First Responder Training Module

5a. CONTRACT NUMBER F08637-03-C-6006
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER 63851D
5d. PROJECT NUMBER OAFT
5e. TASK NUMBER 00
5f. WORK UNIT NUMBER OAFT0177

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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Tyndall AFB, FL 32403-5323

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL/MLQD

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-ML-TY-TP-2005-4607

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution Statement A: Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES
AFRL/MLQ Public Affairs Case # 06-028. Document contains color images.

14. ABSTRACT
Evaluated composite materials and their coatings found on aircraft. Initial testing was accomplished using the ASTM/ NFPA cone calorimeter. The cone calorimeter measures the time to ignition under standard heating conditions and the heat output after ignition of burning composite. The more flammable and most frequently occurring materials were further tested with medium scale apparatus developed by the FAA as a standard method for evaluating burn through. Results were analyzed for composite fire fighting and protection recommendations. University of Delaware (UD) Center for Composite Materials has done a considerable amount of modeling to predict the best testing parameters for thermo-mechanical performance analysis, has manufactured composite materials and has begun testing. Developed a training course for composite material education in conjunction with HQ AFCESA, UD and University of Maryland Fire School for the DoD Fire Academy.

15. SUBJECT TERMS
composite materials, aircraft coatings

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
U	U	U	SAR	33	Virgil Carr
					19b. TELEPHONE NUMBER *(Include area code)*

Outline

- AFRL Introduction
- Hammer IPT
- Composite Wing Burn
- Composite Fire Safety Initiative Consortium
- Fire Safety Course
- ACC Composite Fire Research
- SBIR Effort: Intumescent Paint

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Fire Protection Research Overview

- Programs Vary from Research to Technical Validation
  - 6.2 Research
    - Molecular Modeling of Foams
    - Micro-encapsulated Water
  - 6.3 Advanced Research
    - Ultra High Pressure Water
    - Composite Fire Fighting
  - Technical Services
    - Large Scale Fire Testing
    - Specialized Equipment Development
- Two S&T Thrusts
  - Materials Hazards Firefighting Technology
  - Fire Suppression Technologies
- Leadership in the Fire Research Community
  - ABL Fire Protection
  - New Aircraft Composite Fire Testing
  - Aircraft Hanger Fire Protection
  - Weapons Storage Fire Suppression

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Mission

Conduct Exploratory and Advanced Research in Fire Fighting and Rescue Technologies; Develop Improved Suppression/Mitigation Agents, Specialized Equipment, and Techniques Required to Counter New and Evolving Fire Threats to DoD/Federal Systems and Operations.

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Who We Are and What We Do

- Our Team
  - Electrical, Mechanical, Civil, Chemical and Fire Protection Engineers/Technicians. Chemists, Occupational Health, Safety, and Toxicology Specialists. AutoCAD, Mechanical Desktop and Computational Fluid Dynamics Capability

- Types of Fire Evaluations
  - Large Scale Hydrocarbon Fires
  - Munitions Fire Suppression
  - Protective Clothing and Equipment
  - Composite, Oxidizer Enriched and Metal Fires
  - Aquatic Toxicity and MIL SPEC Extinguishment/Burnback Testing

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Fire Research Laboratory

- Bench-top and Walk-in Hoods for Controlled Fire Burns
- FTIR: Standard and Open Path FTIR
- Ion, Gas Chromatograph
- Thermal Protection Performance Tester
- Elemental Analyzer
- Cone Calorimeter
- Four Data Acquisition Systems
- Drop Volume Tensiometer
- Langmuir Blodgett Trough
- High Temperature (1500C) DSC/TGA

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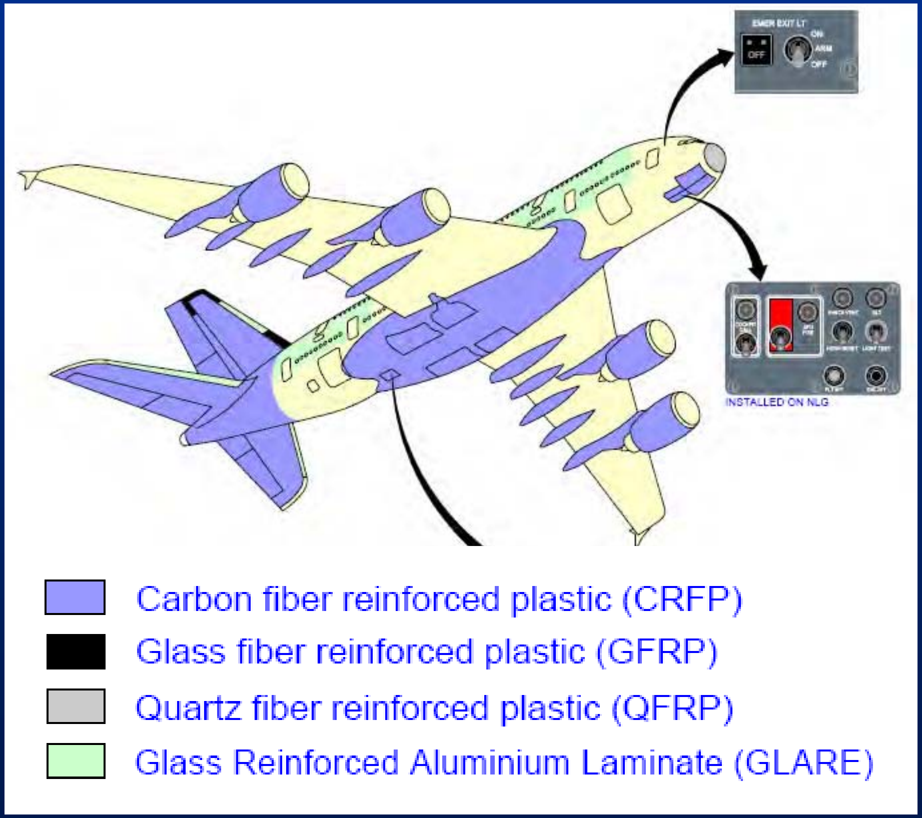
Medium-Scale Fire Test Facility

- **Capabilities**
  - Designed for Medium-Scale Fire Research Tests
  - Environmentally Controlled Ventilation and Gas Scrubber System
  - Flexible Fire Evaluation Configuration
- **Example Experiments**
  - Composite Aircraft Burns for HAMMER IPT (Hazardous Aerospace Materials Mishap Emergency Response)
  - MIL SPEC Agent Extinguishment and Burnback
  - Agent Testing

Composite Material Research Introduction

- Increased use of composite materials in aircraft
- Need for methodology to assess and understand fire damage
- Initial Effort with Composite Wing



HAMMER IPT Program Elements

- Composite material combustion products
- Inventory of HAM locations/quantities on Air Force weapon systems
- Plume modeling capability to determine down wind exposure levels
- Burn composite aircraft structure under load to simulate crash conditions
  - Composite fiber exposures during aircraft crash recovery
  - Crews perform simulated response and recovery procedures
  - Air sampling to determine appropriate respiratory protection requirements

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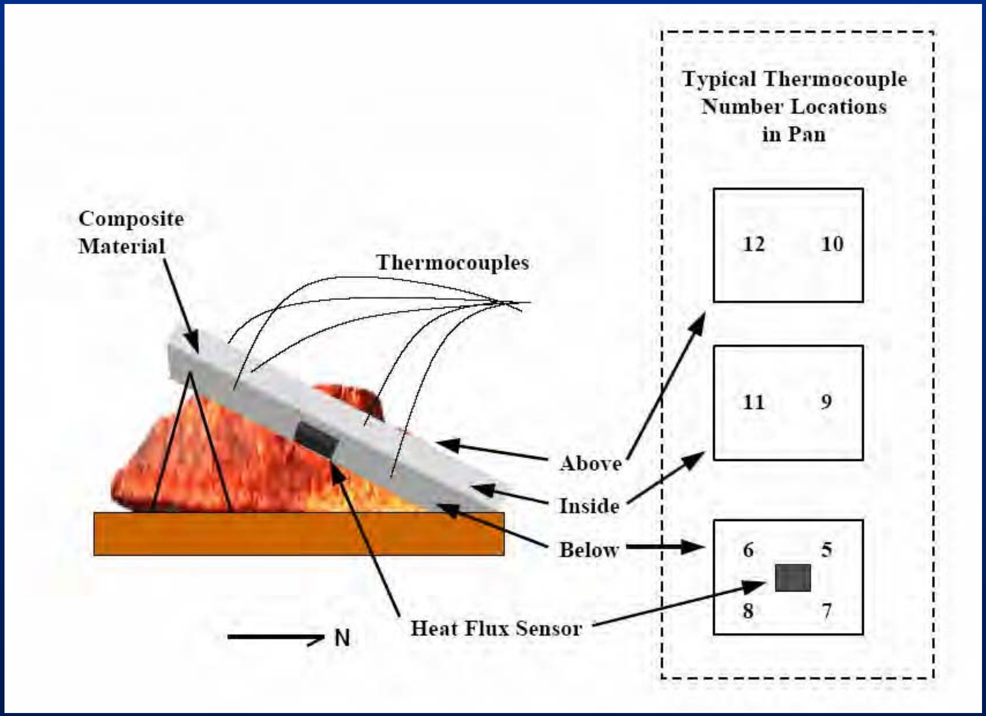
HAMMER Burn 2000



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Key Results

- Persistent smoldering for hours after “fire out”
- Dust and organics filtration required
- Provide basis for procedures outlined in AF Technical Order (TO) 00- 105-9 Aerospace Emergency Rescue And Mishap Response Information

	Composite Hazard	
Task	Low	High
No/light movement	Level 1 -long sleeve, leather glove with nitrile glove	Level 2 -add coveralls and dust mask
Aggressive handling	Level 2/3	Level 3 -full-face air purifying respirator

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AIRFRAME MATERIALS

F/A-22A

MATERIALS DISTRIBUTION

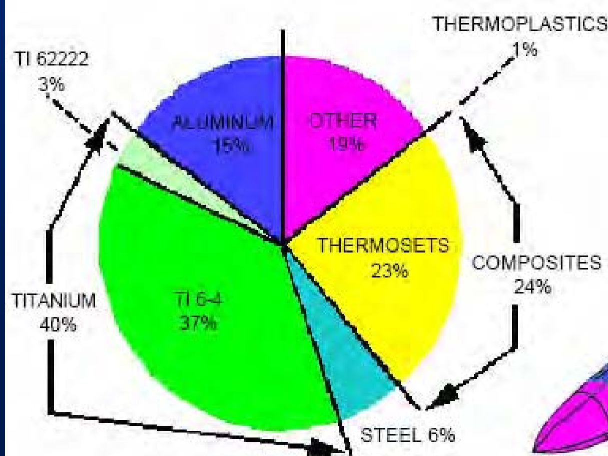
NOTE:

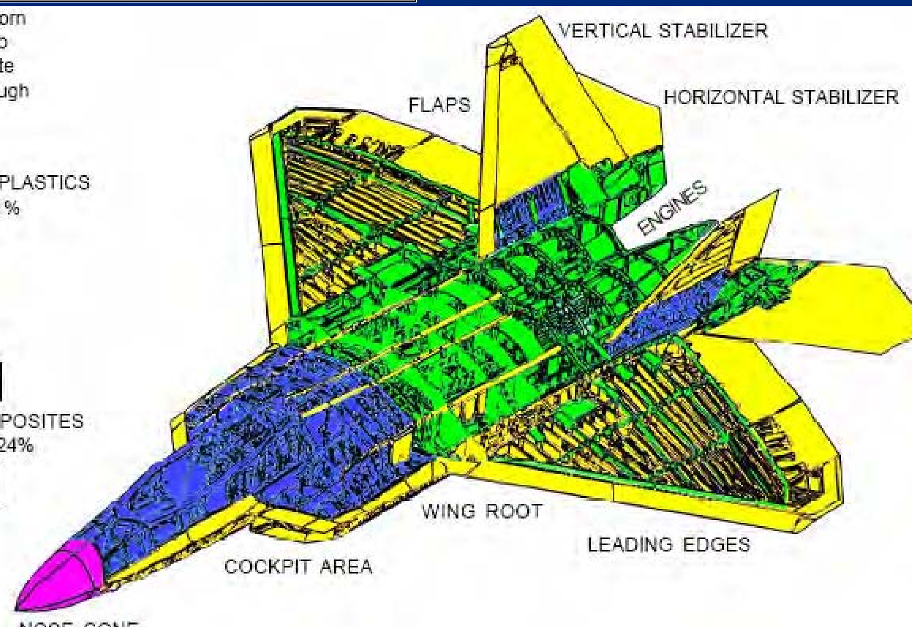
Organic composite structural laminates are made up of stacks of oriented thin lamina that consolidated under heat and pressure. Each lamina consists of a layer of high-strength, high-modulus, low-density reinforcing fibers embedded in a resin matrix. Fibers typically are materials such as carbon, boron, Kevlar 49, or fiberglass. The matrix can be either a thermosetting material such as epoxy, bismaleimide, or polyimide, or a thermoplastic material. If the matrix is thermosetting, a solid material is formed that cannot be reprocessed. Thermoplastic materials, however, can be reshaped by reheating and reforming.

MATERIALS	MATERIALS LOCATION
OTHER	NOSE CONE
ALUMINUM	AFT OF NOSE CONE TO WING ROOTS AND BASE OF VERTICAL STABILIZERS
ALUMINUM BERYLLIUM (ALBEMET)	ALL OVER ACFT, MOSTLY NOSE AND SURROUNDS AVIONIC RACKS (EXTREME RESPIRATORY HAZARD)
ALUMINUM COPPER	AIRCRAFT BUSHINGS
TI 6222 (TITANIUM)	WING AND BODY SPARS, ENGINES
TI 6-4 (TITANIUM)	AND LOWER BASE OF STABILIZERS
STEEL	NOSE AND LANDING GEAR
THERMOPLASTICS (COMPOSITES) & THERMOSETS (COMPOSITES)	LEADING EDGES, FLAPS, HORIZONTAL STABILZERS, WING, & BODY SPARS
CuBe (COPPER BERYLLIUM)	AIRCRAFT BUSHINGS

WARNING

Self Contained Breathing Apparatus should always be worn during firefighting, rescue, and when removing bunkers to prevent respiratory complications from inhaling composite fibers and dust. Serious health problems will result through failure to observe this warning.





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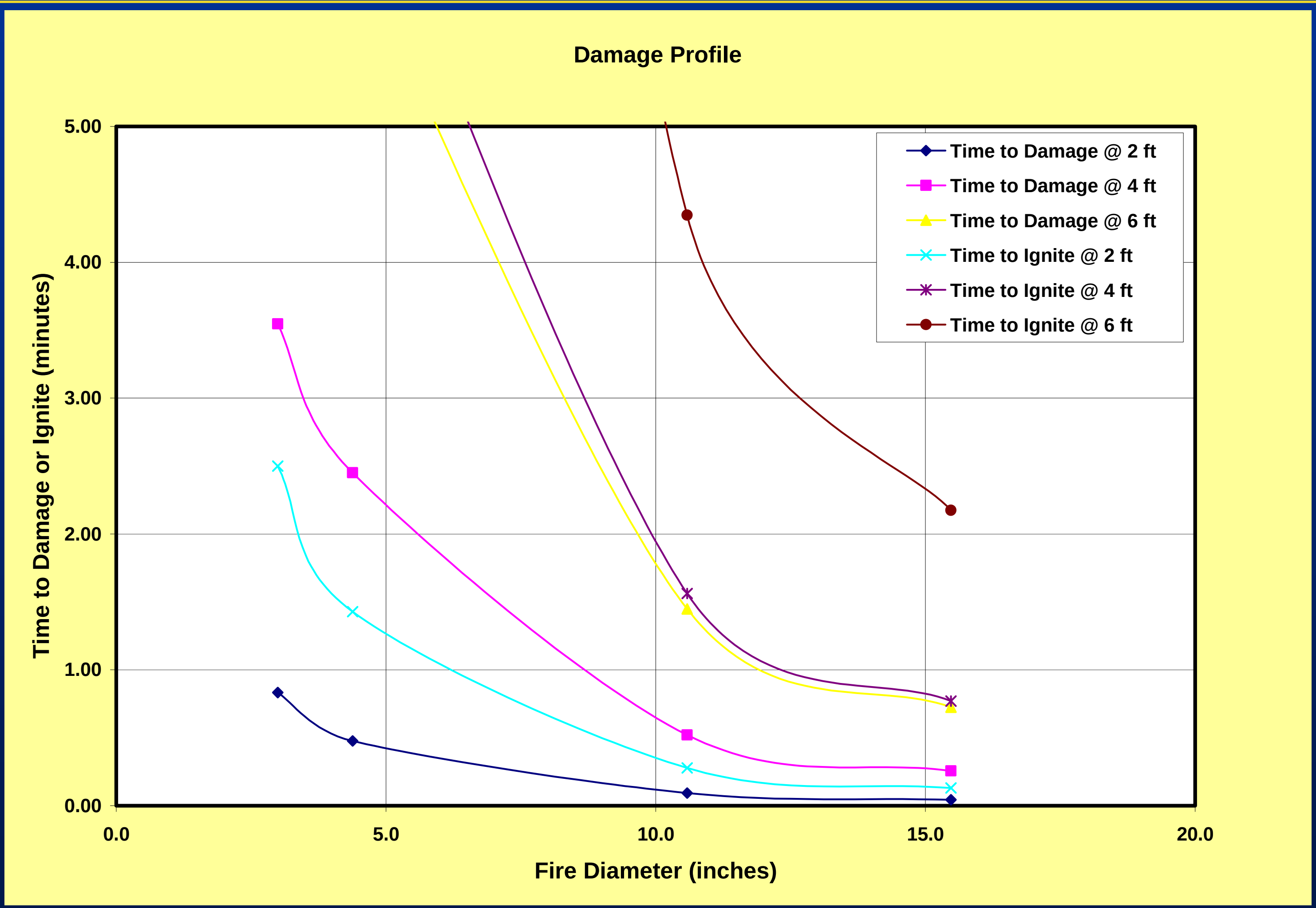
Extrapolated Damage Profile



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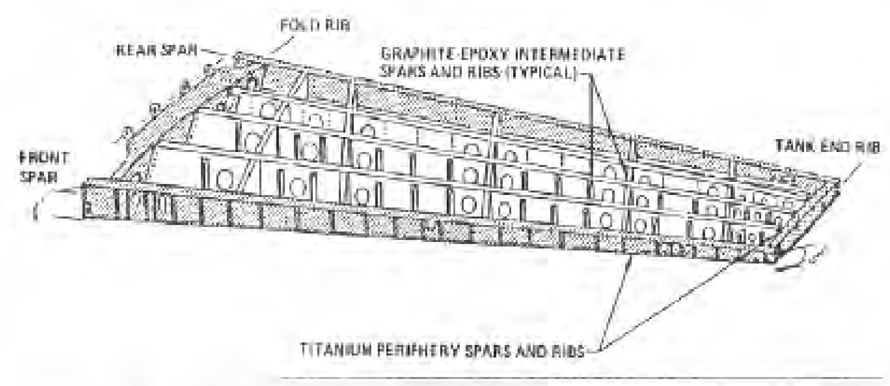
Composite Wing Burn

- Two full scale wing burns were completed
- Pool fires under static wing
- Immediate Response
- Delayed Response
- Data Collected
- One minute exposure
  - Significant variations in properties
- Five minute exposure
  - Gross degradation levels
  - Significant resin loss and fiber damage



- IM6/3501-6 Graphite Epoxy Planked Skin Design
- Fabric Surface Ply, Tape Laminates

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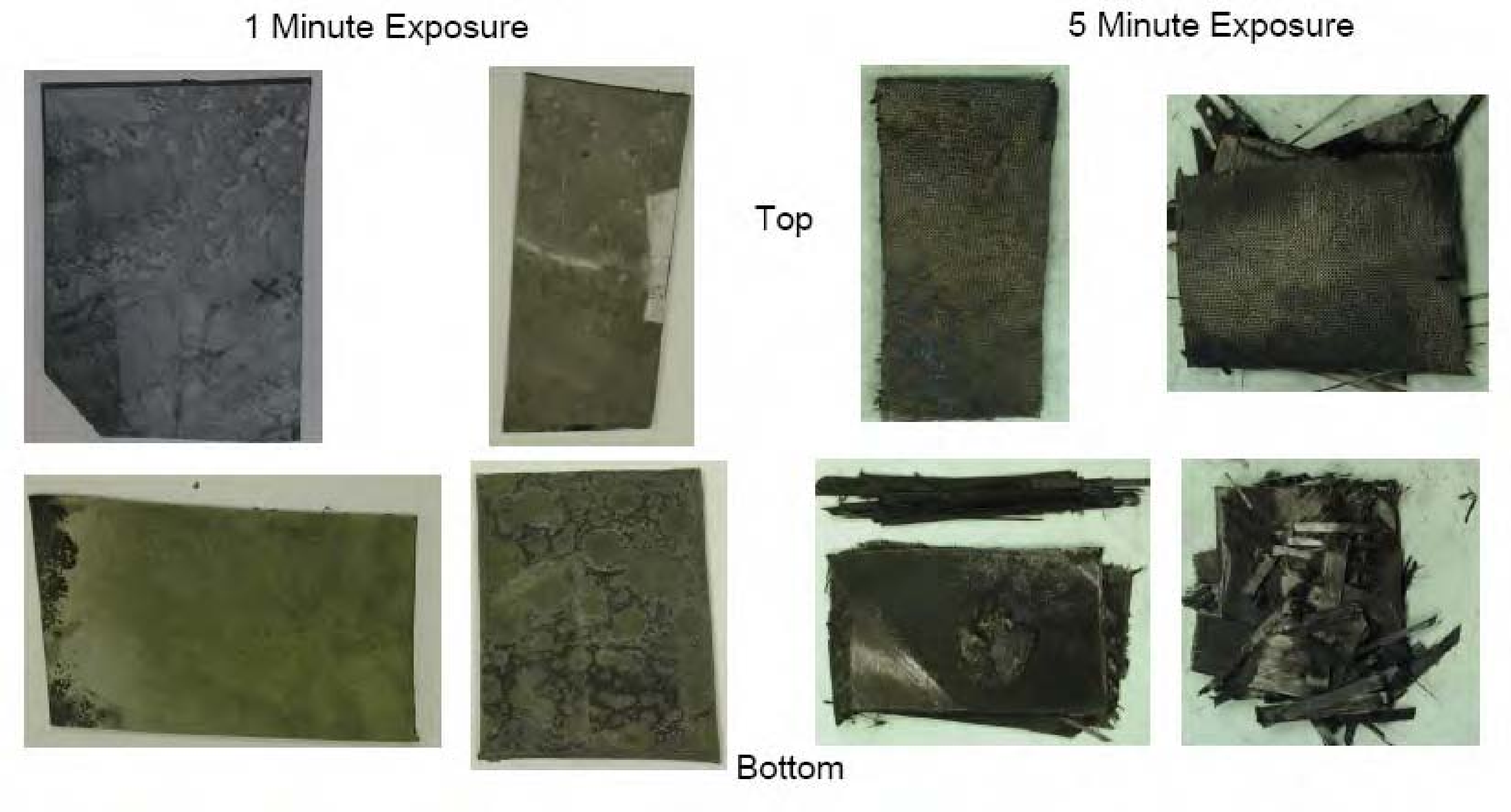
Examples of Damage



Composite Fire Safety Initiative Consortium (CFSIC)

- Provide civilian and military firefighters with the education, methodologies and technologies needed to safely extinguish composite material fires
- Funded in FY04 by the Strengthening the Mid-Atlantic Region for Tomorrow (SMART) Team

Composite Fire Safety Initiative

- **Technical Goal**
  - Develop a comprehensive post-fire damage assessment methodology for composite structures
  - Platform – Carbon/BMI structure
- **Approach**
  - Thermal models to predict temperature history in composite based on heat source
  - Understand resin cure/degradation kinetics based on thermal history

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Composite Fire Safety Initiative

- Findings
  - Traditional definition of degradation (weight loss based) not applicable for mechanical performance
  - Tg (glass transition) change is not a good indicator of degradation
  - Developing models to correlate polymer chemical changes to mechanical properties

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Composite Fire Safety Course

- Focuses on:
  - Handling composite materials incidents
  - Personal protective equipment
  - Decontamination of responders
- Expected to reduce firefighter injuries
- Intended audience
  - > 10,000 DoD firefighters
  - Civilian firefighters
  - First responders

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Composite Fire Safety Course

1. Introduction to Composite Materials
2. Hazardous Material Response and Mitigation Refresher
3. Composite Material Incident Hazards and Life Safety
4. Composite Material Fire Behavior, Strategies and Tactics
5. Extinguishing Agents and Fixants for Composite Materials
6. Written Examination

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Composite Fire Safety Course

- Pilot Course at Dover AFB, February 2005
- Reviewed by AFCESA, Air Force Hazmat Specialists, and Air Force Composite Experts
- Delivering course to Air Force Fire Chief
- Training commercially available through the Maryland Fire and Rescue Institute or Applied Research Associates

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ACC Composite Fire Research

- Phase 1: Lab Scale Screening
- Phase 2: Intermediate Scale Experiments
- Phase 3: Development of fire fighting and fire protection recommendations
  - Operational fire risk assessment
  - Procedures and training to mitigate composite fires
  - Propose experiments, equipment and technology to reach acceptable levels of risk

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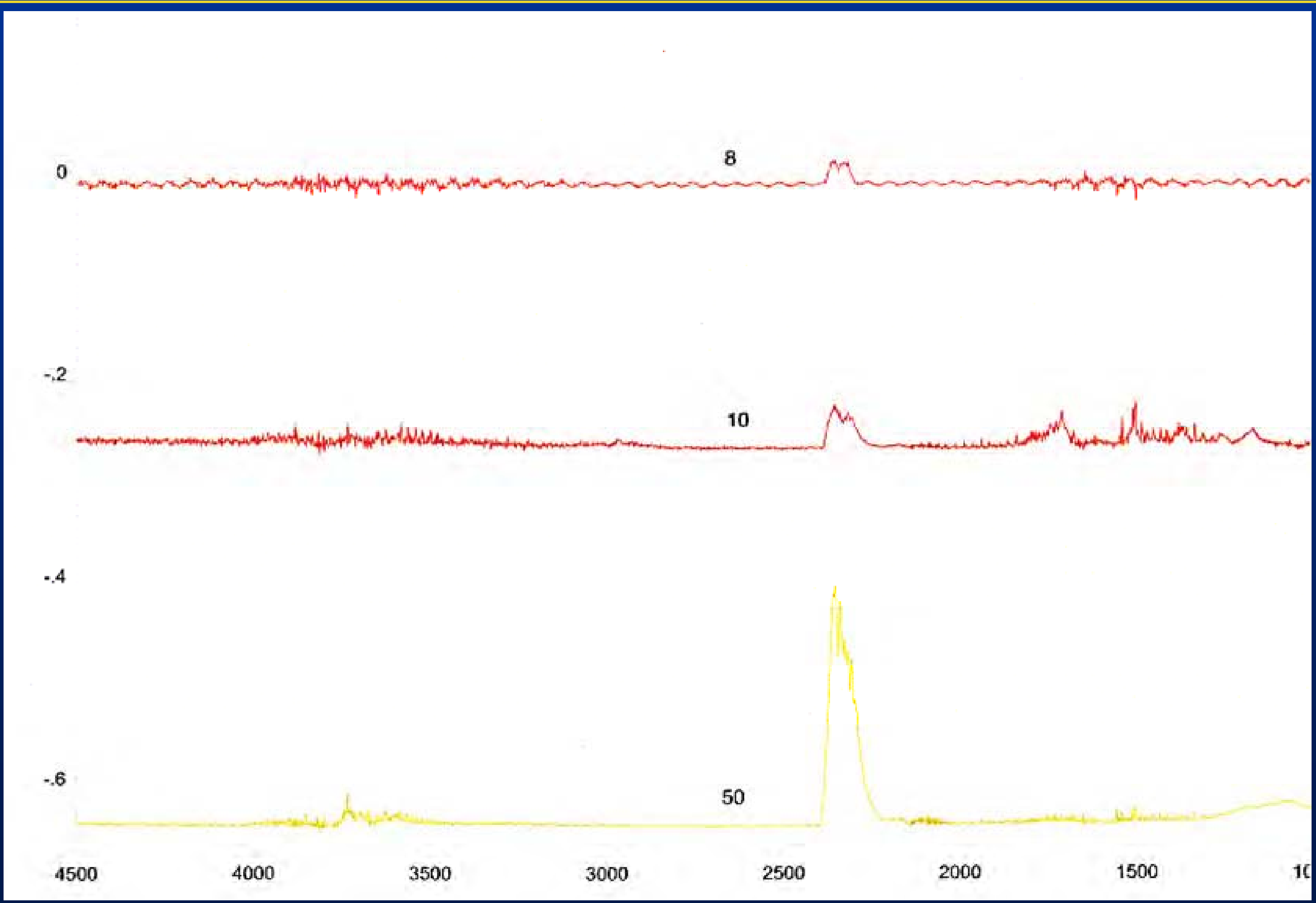
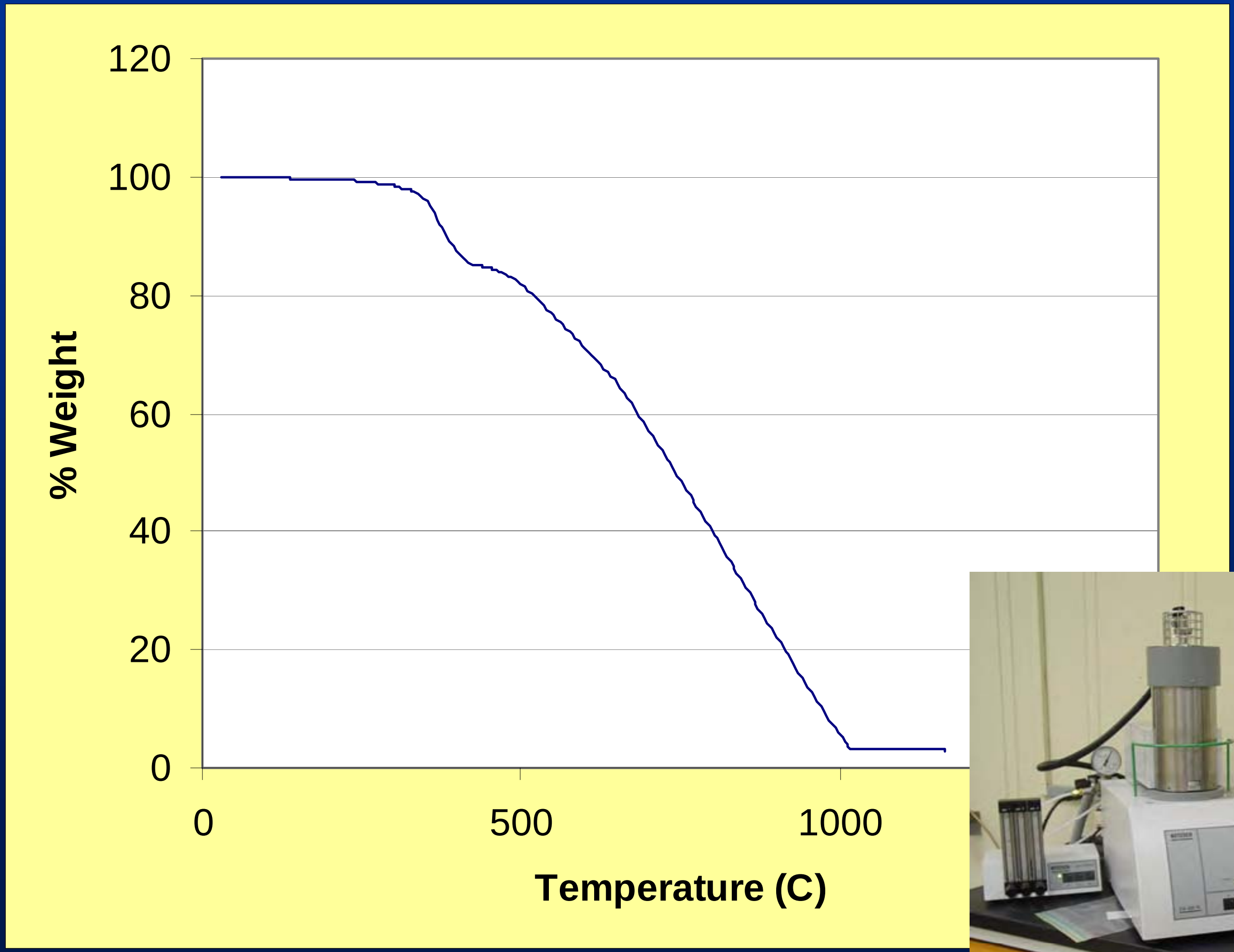
IR Spectra



Example of TGA Results



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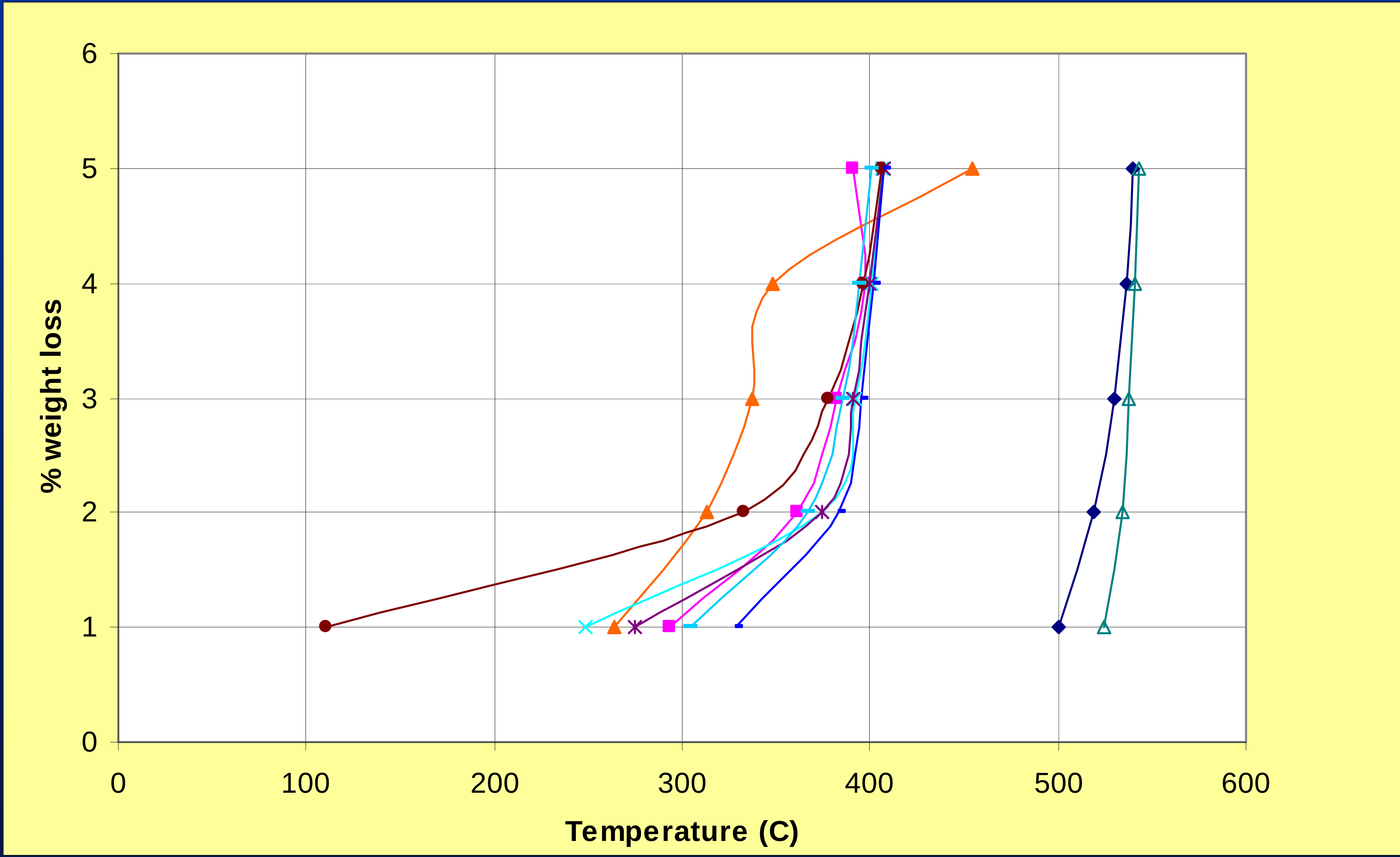
Matrix Decomposition



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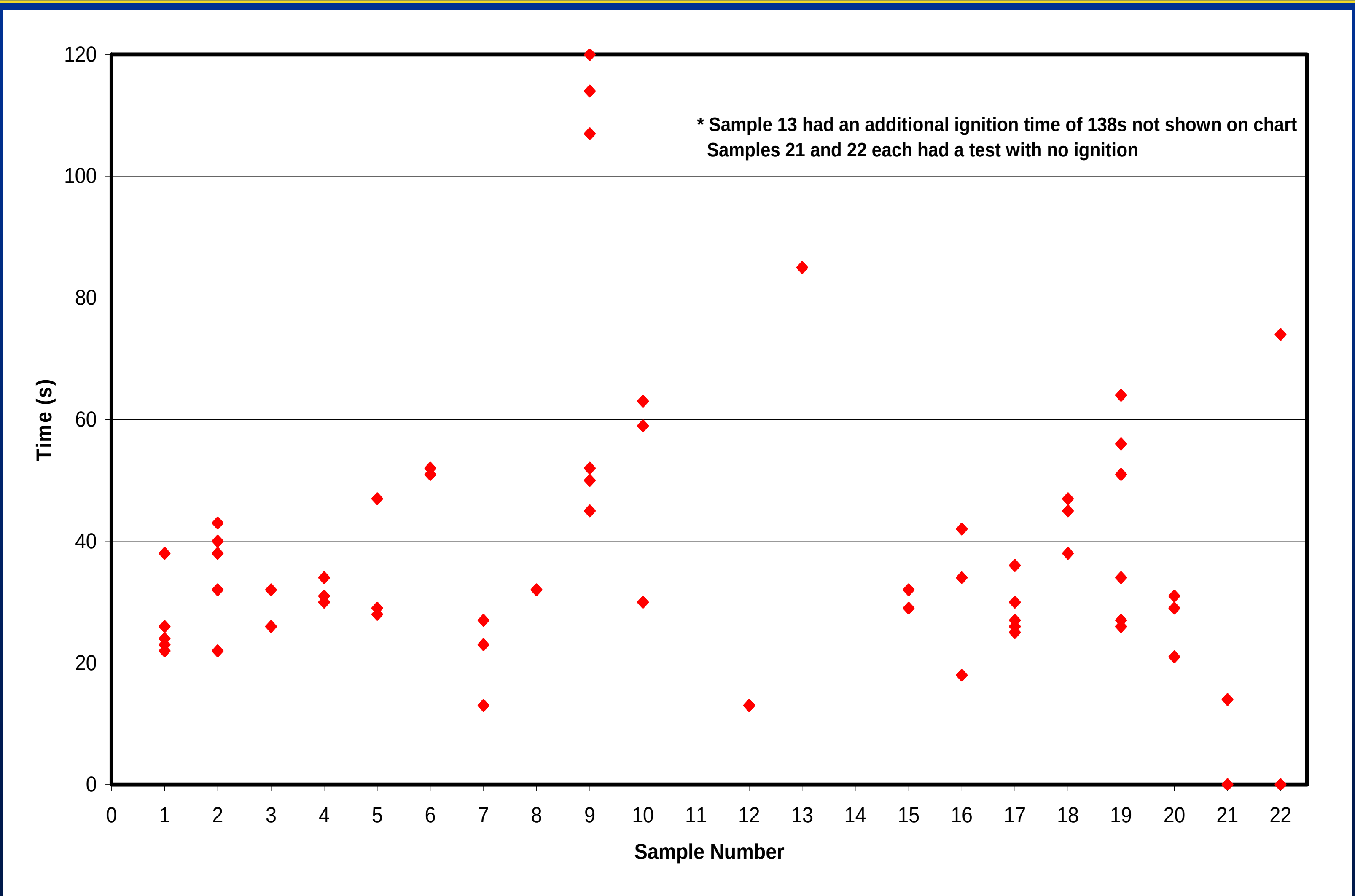
Burn-Through Experiments

- Video

Ignition Time



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Results

- Heat fluxes compare with one meter diameter jet fuel fire located within 6 feet of an aircraft is roughly equivalent to 75 kW/m2 exposure in the cone calorimeter.
- All composite materials screened did ignite at exposure to 75 kW/m2 heat flux.
- Many materials ignite in under 50 seconds in the horizontal position.
- Results from the non destructive investigation confirmed that composite materials can become severely damaged from thermal impingement with little or no visual clues as to the area or extent of fire damage.
- Thermogravimetric analysis provided data on structural integrity and provided confirmation of sample.

Small Business Innovative Research: Lightweight Durable Intumescent Paint

Objectives

- Develop a lightweight, durable intumescent paint applicable to composite parts inside and outside fighter aircraft
- Increase ignition time to 5 minutes when tested in cone calorimeter at 75 kW/m^2
- Reduce flame spread
- Weight < 0.5 oz/ft^2, durability equivalent to current technology, compatible with low observable coatings
- Complies with applicable environmental guidelines

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Small Business Innovative Research: Lightweight Durable Intumescent Paint

Progress

- Developed and tested a lightweight composite protective coating combining a polysilazane preceramic binder with glass microspheres and intumescing agents
- 8X increase in ignition time.
- >60% reduction in peak heat release rates
- Samples remain intact and retain significant residual strength
- Retained 34% of original resin

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Small Business Innovative Research: Lightweight Durable Intumescent Paint

Summary

- Advanced composite material on aircraft and other technologies is still a major concern for both the military and civilian users
- AFRL Fire Research has a Long History in Composite Material Research
- Rich, Ongoing Program to Evaluate Crash/Rescue Hazards Associated with Large Scale Use of Aerospace Composites
- Military and Civilian Goals are not Mutually Exclusive
- AFRL Fire Research Group is continuing their efforts in these areas and continuing to build relationships with other groups working in this field

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